Policy system for palm oil based-bioenergy

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Abstract: Policy system for palm oil based bioenergy sustainability or Polsysbios is an intelligence decision support system (iDSS) in developing palm oil bioenergy. This application is a software prototype to determine adaptive policy strategies based on the sustainability status and existing institutional conditions. The purposes of this research are: 1) to obtain the sustainability status of bioenergy development based on sustainability aspects, consisting economic, social and environmental aspects; 2) to obtain the institutional status based on constraint elements and supporting elements conditions; 3) to determine the best policy strategy based on sustainability status and institutional condition. The policy strategy is based on 12 rules that have been developed. Through the implementation of the Fuzzy Inference System (FIS) Method, it has been obtained that the sustainability index of environmental, social and economic aspect, is 1.995, 1.004 and 2.000 respectively. Whereas the constraints and institutional support elements status are 2.6665 and 1.9995 respectively. Thus it is also known that the sustainability status of bioenergy development is still unsustainable with institutional status described as fairly good. The policy strategy recommendation is to improve the management of environmental, social and economic aspects and increase institutional support towards the sustainability of bioenergy development.

1. Introduction
Development and utilization of bioenergy in Indonesia has not given a positive impact on sustainability efforts. Previous studies have shown that of the three aspects assessed namely environmental, social and economic, sustainability status is still relatively low [1]. Therefore, a fundamental improvement effort is needed, one of which is through the design of bioenergy policies.

The Indonesian government has targeted the provision of electricity to the community sourced from bioenergy development of 5.5 GW in 2025 and 26.0 GW in 2050. However, due to various problems, until 2017 it has only been realized at 1.84 GW [2]. Theoretically the potential of bioenergy for electricity reaches 32.6 GW, this means that from the potential development and utilization of bioenergy, only 5.6% of the total potential exists [3].

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IOP Conf. Series: Earth and Environmental Science **472** (2020) 012060 doi:10.1088/1755-1315/472/1/012060

Fundamental efforts that have been made by the Indonesian government to increase the contribution of bioenergy in meeting national energy needs including through the establishment of various energy regulations and policies. However, the preparation of bioenergy policies also needs to pay attention to various conditions and existing needs. Alignment between policies needs to be considered in order to avoid contradictions and misunderstandings at the implementation stage. Institutional coordination and governance among various stakeholders also influences the success of development efforts and the smooth running of all programs that have been set in each of the rules and policies.

Designing a policy is not an easy matter. According to Purkus [4], many uncertainty factors will be faced by policy makers during the bioenergy policy formulation process, including the sustainability factors towards the development of bioenergy, cost factors, resources and technology, and future energy market conditions. Information and conditions can change at any time, this results in policy adjustments requiring quite high costs.

The design of policies in such complex problem situations characterized by so many uncertainties requires an approach that is able to see every problem as a single integrated and holistic, one of which is the system approach. The systems approach is one alternative that can be used in obtaining effective solutions [5]. With a system approach, the search for solutions to problems that will be outlined in policy and development strategies, can be done through in-depth analysis of each aspect of the needs and constraints of various stakeholders, then aligned with the expected goals and other supporting factors.

According to Marimin [6], the system approach can be carried out using a computer or without using a computer. However, computers will make it easier to use simulation models and techniques, especially in dealing with fairly broad and complex problems that have many variables, data and interactions that affect each other. One system approach technique that relies on computer capabilities in the decision making process is to use intelligent systems. Marimin [7] also explains that, expert systems are intelligent computer software that uses inference knowledge and procedures to find solutions to problems that are quite complex and complex or require the ability of an expert to solve them. The use of intelligent systems is one of the best alternatives in solving problems using computers that are supported by artificial intelligence techniques.

This study aims to produce a smart decision support system (iDSS) design, in determining the policy strategy for developing oil palm bioenergy, especially in meeting the electricity needs of the community. The determination of policy strategies is based on the status of sustainability and institutional conditions. The system built is named the Policy System for Bioenergy Sustainability (Polsysbios).

2. Methodology

2.1 Research framework

In a previous study, Papilo [1] has conducted an assessment of the sustainability index of bioenergy development in Indonesia. In this study 6 indicators have been identified that have a significant influence on the sustainability of each aspect. On the environmental aspect, 3 indicators to consider include: 1) greenhouse gas emissions, 2) soil quality, and 3) air quality. Furthermore, on the social aspect, 2 indicators that need to be considered include: 1) change in income and 2) bioenergy used to expand access to modern energy services. Then on the economic aspect, one indicator that needs attention is infrastructure and logistics for bioenergy distribution. Furthermore, the six indicators become input parameters in evaluating the sustainability status of bioenergy development in Indonesia.

Meanwhile, the two institutional elements being compared include the constraint element and the supporting element. At the constraint element, 5 sub-critical elements are identified : 1) lack of investment capital; 2) investment return; 3) investor interest in investing; 4) synchronizing government regulations and policies; and 5) coordination of roles between government institutions. While in the supporting elements, 5 sub-elements have been identified as follows: 1) the availability of a bioenergy development budget in the State Budget; 2) continuity of energy production to the community; 3) experience of the success of the bioenergy development program; 4) the opportunity for cooperation is quite large and 5) the existence of guaranteed supply of raw materials is quite high. The trade-off between these constraints and carrying capacity becomes the basis for evaluating the institutional status of bioenergy development. The Polsysbios design framework is presented in Figure 1.

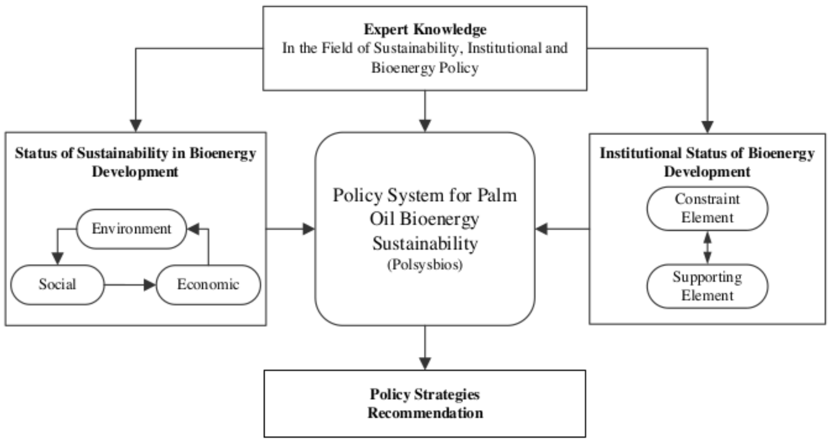

Figure 1. Diagram of the polsysbios design framework.

2.2 *Research stages*
This research consists of stages including: 1) knowledge acquisition; 2) knowledge representation, 3) inference process; 4) fuzzification, 5) defuzzification and 6) system design, and 7) system testing and implementation. The following is an explanation of each stage:

2.2.1 Knowledge acquisition. Is a stage that seeks to absorb knowledge from experts related to the variables studied. The approach adopted in this stage includes the expert opinion poll and through a literature review. In this study, knowledge acquisition was carried out to determine the threshold parameters of each sustainability indicator and determine the sustainability status of each aspect and institutional status. The results of the acquisition of knowledge then become the knowledge base of the designed system.

2.2.2 Representation and knowledge base. Is a knowledge base in formulating and solving problems which subsequently become the basis in the decision making process. The knowledge base is based on expert knowledge of available facts. In this study, facts are the existing conditions and ideal conditions of each indicator.

2.2.3 Inference process. A stage of making conclusions on the rules or logic that has been built. In this research the inference process is carried out using fuzzy logic, where each parameter is arranged in the form of fuzzy sets primarily to represent and manipulate vague (unclear) information in the process of drawing conclusions.

2.2.4 Fuzzyfication. At this stage, the input system (crisp) of the fuzzy system is transferred into the fuzzy set to be used in calculating the truth value of the premise of each rule in the knowledge base.

2.2.5 Defuzzyfication. This stage is the opposite of the fuzzyfication stage, where at this stage the value of the fuzzy set obtained from the composition process is converted back into crisp form using the Centroid Method.

2.2.6 System design. To simplify the process of calculating and determining policy strategies, the next step is to design an application system interface. The application system development is done using Java NetBeans IDE based software version 8.1.

2.2.7 System testing and implementation. After the application system is built, the next step is to test with several possible scenarios. At this stage, the implementation is carried out using dummy data.

2.3 Polsysbios system configuration

Polsysbios is divided into four main components, namely database management system, model base management system, knowledge base management system and dialogue management system. Polsysbios system configuration diagram is presented in Figure 2.

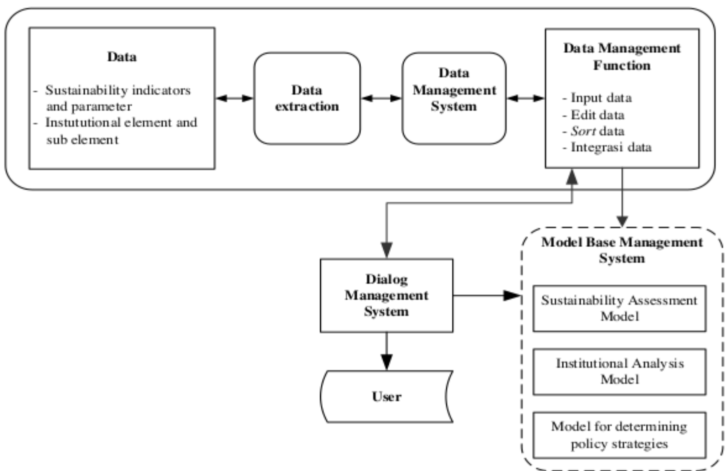

Figure 2. Polsysbios system configuration diagram.

3. System modelling

3.1 Database management system

This study uses secondary data, which is the result of a previous study conducted by FAO [8]. In accordance with its function, the data collected is grouped into two categories, namely: 1) Data related to the sustainability indicators of each aspect along with parameters and thresholds, and 2) Data related to institutional conditions based on comparable elements consisting of obstacle elements and factor elements supporters. A database of each indicator of sustainability, institutional elements and sub elements along with their thresholds is presented in Table 1 and Table 2.

IOP Conf. Series: Earth and Environmental Science **472** (2020) 012060 doi:10.1088/1755-1315/472/1/012060

Table 1. Database of sustainability indicators.

Aspects	Indicators	Parameter	Unit	Threshold)	Target
Environment	GHG emission	CO_2 emission	g CO_2 eq/MJ	< 50 or > 150	Min
	Soil quality	Soil of Carbon	%	> 10% or < 1%	Max
	Air quality	Non-CO_2 emission	mg/ MJ	< 200 or > 600	Min
Social	Change in income	Average worker wages	Minimum wage (MW) level	> 2 x MW or < MW	Max
	Bioenergy used to expand access modern energy service	Percentage of growth in installed capacity of bioenergy power plants per year	%	> 30% or < 10%	Max
Economic	Infrastucture and logistic for bioenergy distribution	Highway conditions	Condition level	Inadequate - Very adequate	Max

Table 2. Database of institutional elements.

Elements	Sub Elements	Scale	Target
Constraints	1.Limitations on investment capital	[1 ; 3]	Min
	2.Lack of return on investment	[1 ; 3]	Min
	3.Low of investor interest	[1 ; 3]	Min
	4.Difficulties in synchronizing government regulations	[1 ; 3]	Min
	and policies	[1 ; 3]	Min
	5.Problems in coordinating institutional roles		
Supporting factors	1.Availability of sufficient state budget	[1 ; 3]	Max
	2.Electricity supply to the community	[1 ; 3]	Max
	3.Previous success experience in the bioenergy	[1 ; 3]	Max
	development program	[1 ; 3]	Max
	4.Opportunities for cooperation in bioenergy	[1 ; 3]	Max
	development		
	5.Guaranteed supply of raw materials		

3.2 Model base management system

3.2.1 Sustainability status determination model. Determination of the sustainability status of bioenergy development is based on an assessment of the sustainability index in each aspect of sustainability consisting environmental aspects, social aspects and economic aspects. The sustainability status of bioenergy development is classified into 4 levels consisting of unsustainable, less sustainable, moderately sustainable and sustainable.

Furthermore, the fuzzyfication process is carried out to get the membership value of the fuzzy set of each indicator. Representation of the value of the fuzzy set of indicators on environmental aspects is done using the calculation of the trapezoid function. Threshold values, obtained based on literacy studies, become the basis for determining fuzzy set values for each level of assessment.

IOP Conf. Series: Earth and Environmental Science **472** (2020) 012060 doi:10.1088/1755-1315/472/1/012060

In the database, it is known that the threshold value of CO_2 emission level indicators ranges from 50 gCO_2 eq / MJ to 150 gCO_2 eq / MJ. These values indicate that the higher the level of CO_2 emissions (GHG), the more negative the impact on the sustainability of environmental aspects. This threshold value becomes the basis in determining the fuzzy set members on the CO_2 emission indicator. Determination of the level of CO_2 emissions is grouped into four levels. Linguistic and fuzzy membership functions of each level of CO_2 emissions have values such as: low (0; 0; 40; 50), rather low (40; 50; 90; 100), rather high (90; 100; 140; 150) and height (140; 150; 200; 200). The membership function for the GHG indicator can be obtained by the following equation:

$$\mu_{low}(GHG) = \begin{cases} 1, & GHG \leq 40 \\ (50\text{-}GHG)/10, & 40 < GHG \leq 60 \\ 0, & \text{the other} \end{cases} \tag{1}$$

$$\mu_{high}(GHG) = \begin{cases} 1, & GHG > 150 \\ (GHG\text{-}140)/10, & 140 < GHG \leq 150 \\ 0, & \text{others} \end{cases} \tag{2}$$

$$\mu_{rather\ low}(GHG) = \begin{cases} 1, & 50 < GHG \leq 90 \\ (GHG\text{-}40)/10, & 40 < GHG \leq 60 \\ (100\text{-}GHG)/10\ , & 90 < GHG \leq 100 \\ 0, & \text{others} \end{cases} \tag{3}$$

$$\mu_{rather\ high}(GHG) = \begin{cases} 1, & 100 < GHG \leq 140 \\ (GHG\text{-}90)/10, & 90 < GHG \leq 100 \\ (150\text{-}GHG)/10, & 140 < GHG \leq 150 \\ 0, & \text{others} \end{cases} \tag{4}$$

The next step is determining the fuzzy membership set for each indicator using the 2014 version of Matlab. The trapezoid representation of the fuzzy membership function of the CO_2 emission level indicator can be shown in Figure 3.

Each indicator is represented in the same way as the determination of the CO_2 emission indicator membership function. Then the aggregation process is carried out, namely the integration of the results of the assessment of the sustainability index of each aspect as an input variable to obtain a single value as a basis for determining the sustainability status of bioenergy development.

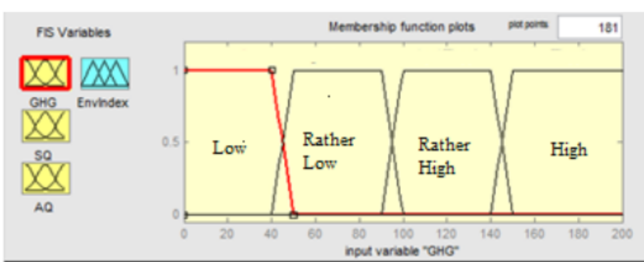

Figure 3. The fuzzy membership function of CO_2 emission indicators (GHG).

The results of the aggregation in the form of a sustainability index will be further fuzzyfied using the Centriod Method. The results of the aggregation of each aspect become input in determining the status of sustainability. The TFN representation of sustainability status is presented in Figure 4.

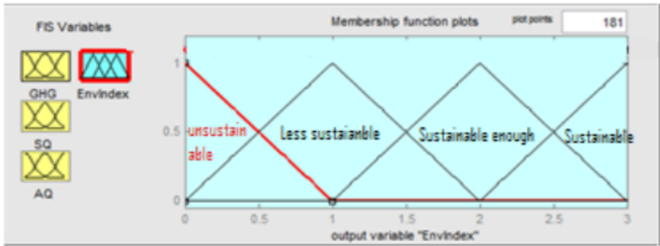

Figure 4. Fuzzy membership function of sustainability status.

3.2.2 Institutional status determination model. The determination of the institutional status of bioenergy development is based on a comparison between the supporting factors and the constraints. Supporting elements are composed of sub-elements that are able to encourage the implementation of bioenergy development programs in Indonesia. The fuzzy membership set for elements and institutional status is represented in three levels consisting of, not good (1; 1; 2), moderate (1, 2, 3) and good (2; 3; 3). The TFN representation of institutional status is presented in Figure 5.

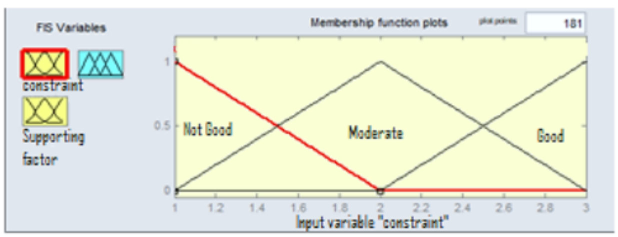

Figure 5. Fuzzy membership function of institutional status.

3.3 Knowledge base management

In this study, knowledge representation is done through the application of production methods. In the production method, procedural knowledge is structured by IF - THEN rules. This rule connects the premise (IF) with the conclusion (THEN). Determination of the number of rules can be done using equation (1). For example, in determining the environmental index sustainability index, there are 3 indicators with a total rating scale of 4 for each. The inference process, starting from the fuzzyfication process, inference, composition and defuzzyfication is carried out 3 times. The inference stages of each variable can be seen in Figure 6.

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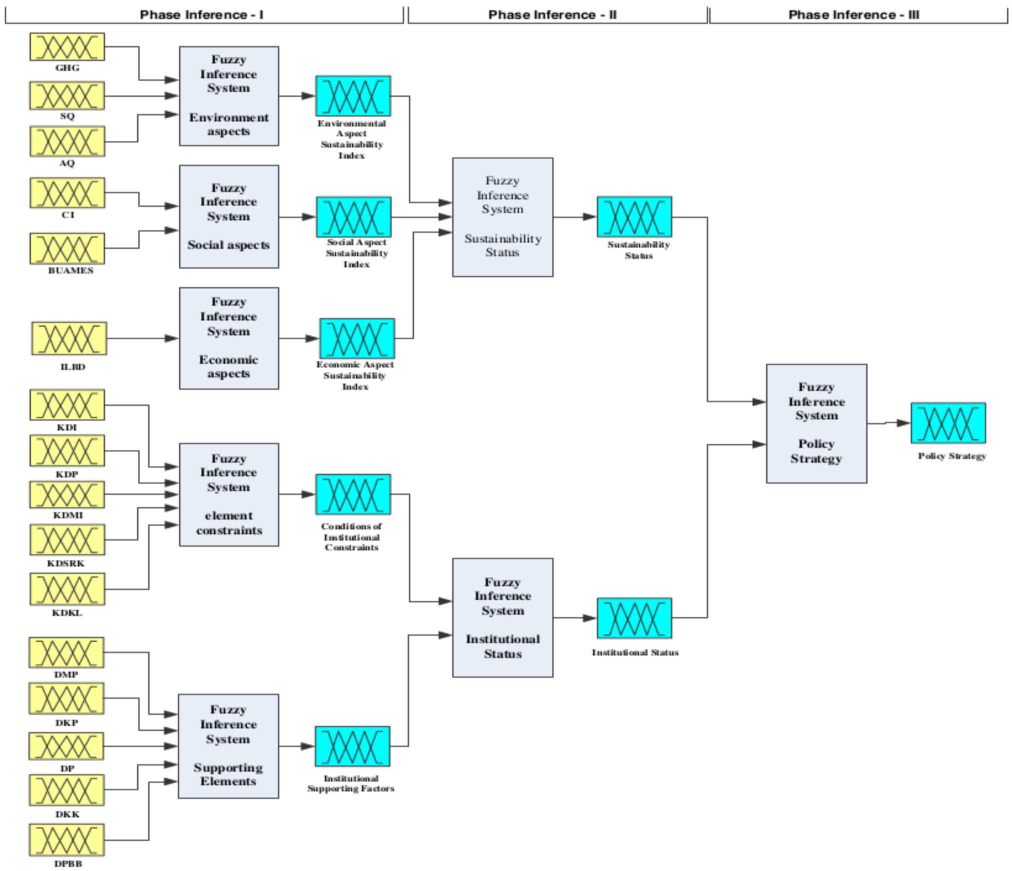

Figure 6. Stages of inference on polsysbios.

In this polsysbios, drawing conclusions in the form of an appropriate policy strategy goes through a series of inference processes, ranging from determining the status of sustainability and institutional status to the determination of policy strategies. The inference method used is min, while the composition method used is max. The combination of these two methods is often known as max-min inference. In general, the determination of the bioenergy development policy strategy is determined through three stages of inference based on input data expressed as crisp values and fuzzy sets, including:

1. Inference - I, conducted to determine the level of sustainability of each aspect of sustainability and the condition of each institutional element based on an assessment of each indicator of sustainability and institutional sub-elements.
2. Inference - II, conducted to determine the sustainability status of bioenergy development based on the three aspects of sustainability and institutional status based on two comparable elements.
3. Inference - III, conducted to determine an appropriate policy strategy, based on the status of sustainability and institutional status in the development of bioenergy.

3.4 Defuzzyfication

For example, the process of fuzzyfication to defuzzyfication manually can be seen in determining the level of sustainability in environmental aspects, where there are three indicators namely CO_2

emissions (GHG), soil quality (SQ) and air quality (AQ). The input-output relationship between indicators and the level of sustainability of environmental aspects is presented in Figure 7.
For example, if: GHG = 42.5 CO_2 g eq/MJ; SQ = 5.3%; and AQ= 250 mg/MJ

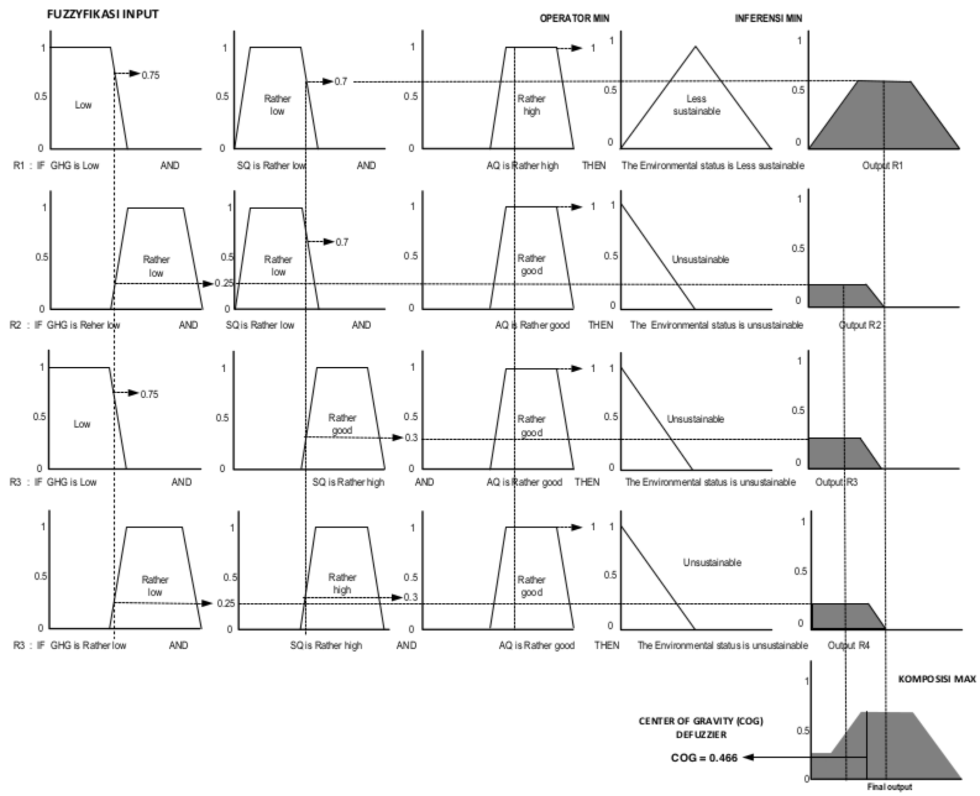

Figure 7. Diagram of the defuzzyfication process.

Based on the membership function of each GHG, SQ and AQ indicator, membership values can be obtained as input data for each indicator. In the GHG indicator, CO_2 emission levels of 42.5 CO_2 g eq / MJ is included in the low membership and rather low with a membership value not equal to 0. SQ indicators with carbon content in the soil of 5.3% included in the membership are rather low and rather high, while for the AQ indicator with an air particulate value of 250 mg / MJ included in the membership is rather good. The membership values of each indicator include:

$$\mu_{low}(GHG{=}42.5){=}0.75 \text{ and } \mu_{rather\ low}(GHG{=}42.5){=}0.25 \quad (5)$$
$$\mu_{rather\ low}(SQ{=}5.3){=}0.7 \text{ and } \mu_{rather\ high}(SQ{=}0.7){=}0.3 \quad (6)$$
$$\mu_{rather\ good}(AQ{=}250){=}1 \quad (7)$$

Furthermore, based on the four premises that were formed and through the application of the min operator, the consequent value of each premise can be known. Thus the reasoning can be carried out as follows:

Rule - 1 (R1) = *IF* GHG is low *AND* SQ is rather low *AND* AQ is rather good *THEN* sustainability status of environment aspect is less sustainable.

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Rule - 2 (R2) = *IF* GHG is rather low *AND* SQ is rather low *AND* AQ is rather good *THEN* sustainability status of environment aspect is unsustainable.

Rule - 3 (R3) = *IF* GHG is low *AND* SQ is rather high *AND* AQ is rather good THEN sustainability status of environment aspect is unsustainable.

Rule - 4 (R4) = *IF* GHG is rather low *AND* SQ is rather high *AND* AQ is rather good *THEN* sustainability status of environment aspect is unsustainable.

3.5 Dialog base management system

The dialog base management system is an application interface that connects the centralized data processing system with the user to assess the status of sustainability, institutional status and simultaneously determining policy strategies based on the conditions of the two parameters. The form of the prototype interface display application of determining the bioenergy development policy strategy, can be seen in Figure 8.

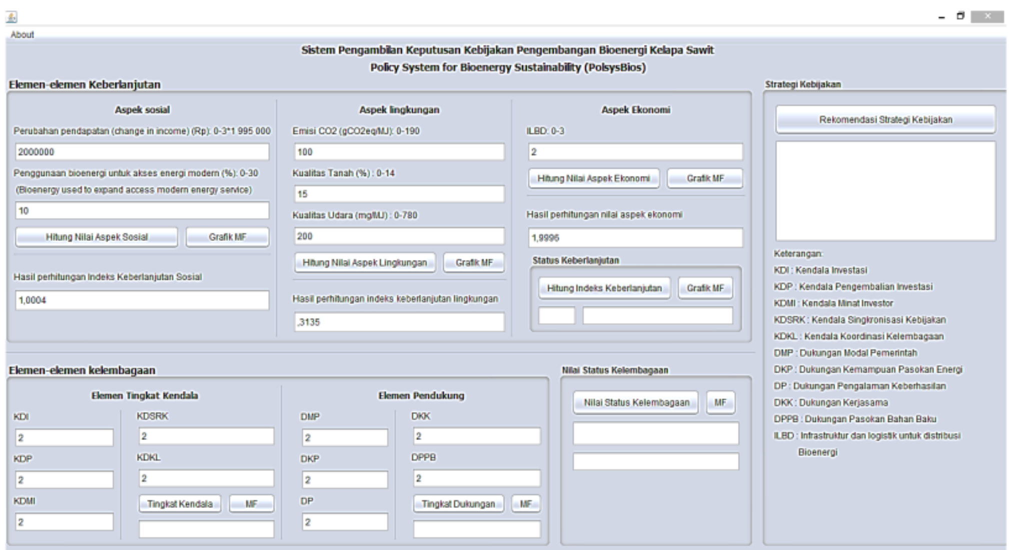

Figure 8. The interface of polsysbios.

3.6 System testing

Furthermore, testing has been carried out by estimating several conditions as an alternative scenario for determining the policy strategy. Testing is done with 4 scenarios, including:

1. Scenario - 1: Ideal conditions
   It is a scenario of determining a policy strategy that can be adopted in conditions where sustainability and institutional status is in good condition.
2. Scenario - 2: Worst condition (extreme)
   It is a scenario of determining a policy strategy when the sustainability status of bioenergy development is in a less sustainable condition and the institutional condition is in a bad condition.
3. Scenario - 3: Unsustainable
   Is a scenario to determine the policy strategy when the sustainability status is in a less sustainable condition but the institutional condition is still in good condition, and
4. Scenario - 4: Institutional problems (institutional problem situation)
   It is a scenario for determining a policy strategy in which the status of sustainability is quite sustainable but the institutional condition is still problematic.

To obtain a policy strategy recommendation, it is strongly influenced by the values of each indicator in each inputted aspect. The results of testing all four scenarios can be seen through Table 3.

Table 3. System test results according to scenarios.

Scenarios	Sustainability				Institutional			Policy Strategy Recomendation
	IS	IL	IE	Sustainability Status	CL	SL	Instituional Status	
1	2.665	2.686	2.686	Sustainable enough	1.001	2.686	Good enough	Improved management of environmental, social and economic aspects and increase institutional support that supports the sustainability of activities
2	0.313	0.313	1.001	Less Sustainable	2.686	1.001	Not good	Improved management of environmental, social and economic aspects and improvement of institutional systems that support the sustainability of activities
3	0.313	0.313	1.001	Less Sustainable	1.001	2.686	Good enough	Improved management of environmental, social and economic aspects and to increase institutional support that supports the sustainability of activities
4	2.686	2.686	2.686	Sustainable enough	2.686	1.001	Not good	Improve management of environmental, social and economic aspects and improve institutional support that supports the sustainability of activities

Noted: IS: Social Index; IL: Environmental Index, IE: Economic Index, CL: Constraints Level; SL: Supporting Level

4. Conclusion

This research has succeeded in obtaining an application design for determining bioenergy development policy strategies based on sustainability status and institutional status. The application that was built is still in the form of a prototype that contains various rules that are integrated into a smart decision support system.

The design of polsysbios has provided several benefits, including: 1) providing a clearer and integrated system picture of one variable with another variable, 2) making it easy for users to search for problems, 3) making it easy for users to get decision recommendations fast and precise, 4) gives users the ability to think like an expert.

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